Resource Department

Hydrogeology Department

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The Hydrogeology Department (HD) consists of more than 50 scientists, postdocs, research associates, and graduate students carrying out a broad range of cutting-edge research in fundamental and applied hydrogeology. HD has expertise in theoretical, experimental, field, and modeling approaches in a variety of research areas, among which are unsaturated zone and fractured rock hydrology, reservoir engineering (geothermal, gas, oil, and hydrates), CO_2 sequestration and nuclear waste isolation, contaminant hydrology, and coupled nonisothermal, geochemical, and geomechanical processes. Highlights of research efforts in these areas over the last two years include the following:

SUBSURFACE ENERGY RESOURCE RECOVERY

Researchers in HD are studying ways to enhance production of energy from subsurface reservoirs containing methane gas hydrates, geothermal energy, and traditional oil and gas resources. In the area of methane hydrates, HD scientists are carrying out a sustained laboratory campaign to uncover fundamental properties of methane hydrates, such as dissociation kinetics and constitutive models, which can be incorporated into the world's leading methane hydrate simulator, TOUGH+Hydrate. Moreover, numerical simulation studies and laboratory experiments were conducted to examine the geomechanical behavior of hydrate-bearing sediments. The potential for significant methane releases from oceanic sediments caused by hydrate dissociation in response to climate change has also been investigated.

Continuing the long tradition of geothermal research in the ESD, staff members in HD are investigating reactive geochemistry in geothermal reservoirs, to devise ways to avoid mineral scaling and maintain injectivity without inducing short-circuiting flow paths. This effort is undertaken using TOUGHREACT, the reactive geochemical simulator developed by HD researchers. HD scientists performed the first quantitative analysis of a novel concept for producing geothermal energy that would use carbon dioxide instead of water as heat transmission fluid, and would accomplish geologic storage of CO_2 as an ancillary benefit. CO_2 was shown to achieve approximately 50% larger heat extraction rates than water.

In collaboration with researchers in the ESD Geophysics Department, HD staff confirmed that viscous fluid flow creates anomalies at low seismic frequencies that can be used to image oil reservoirs. By this method, re-analysis of 3-D seismic data, using frequency-dependent approaches, has revealed hydrocarbon-rich layers where none was detected by standard analysis.

SUBSURFACE REMEDIATION

HD researchers address national and international needs for subsurface contaminant characterization and remediation across the spectrum of approaches. In the lab, HD researchers are investigating some of the nation's most critical subsurface contamination issues, including the chemical evolution of highly alkaline Hanford tank waste, reduction, re-oxidation, and diffusion of uranium (U)VI in sediments, hydraulic properties of unsaturated gravels, and the natural production of transport-enhancing mobile nanoparticles in the subsurface.

Advances in subsurface characterization are expected to follow from HD's work on joint hydrologic and geophysical inversion. Specifically, the approach aims at identifying soil structure, flow and transport properties, and the system state by jointly estimating hydrogeological, petrophysical, and geostatistical parameters, using hydrological, thermal, biogeochemical, and geophysical data. Geophysical models for simulating ground penetrating radar and electrical resistivity tomography have been implemented in the iTOUGH2 nonisothermal multiphase flow and transport simulation and optimization code, enabling us to jointly invert complementary data sets. The approach has been studied extensively using synthetic data, and has been applied to field data at contaminated sites, including those at Hanford and the Savannah River Site

GEOLOGIC CO_2 STORAGE

HD researchers are involved in a wide range of efforts involving field pilot tests, laboratory work, simulation and modeling of coupled CO_2 flow and transport processes, and risk assessment. Theoretical and modeling accomplishments aim at answering fundamental questions about the effects of CO_2 injection on hydrological, geochemical, and geomechanical conditions in a potential storage formation. Field pilot tests of CO_2 injection were performed that included tracer tests, sampling, and geophysical surveys. Numerical simulations were used to design and analyze these tests. Field measurements of CO_2 flux using eddy covariance and accumulation chamber methods were employed to examine the possibility of detecting potential leakage from CO_2 storage sites. These field tests were complemented with theoretical and modeling studies. System-level modeling tools were employed to evaluate the feasibility of carbon sequestration with enhanced gas recovery.

NUCLEAR WASTE DISPOSAL IN THE UNSATURATED ZONE

The motivation for HD's extensive effort in unsaturated zone hydrology and coupled processes is stimulated by the need to understand flow and transport in the unsaturated zone at Yucca Mountain, Nevada. Research by HD scientists in this prominent area includes infiltration and seepage, coupled nonisothermal and geomechanical effects, and transport of radionuclides. The decade-long contributions of ESD and HD staff to the understanding and characterization of the hydrological, thermal, and geochemical conditions at Yucca Mountain (both before and after waste emplacement) are reflected in the technical reports and publications that support the license application to the Nuclear Regulatory Commission. The expertise gained in conceptualizing complex systems and phenomena in unsaturated fractured rock, and the related modeling, laboratory, and field testing, is increasingly applied to nuclear waste programs in other countries, as well as to other characterization and radionuclide transport problems in the U.S.

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